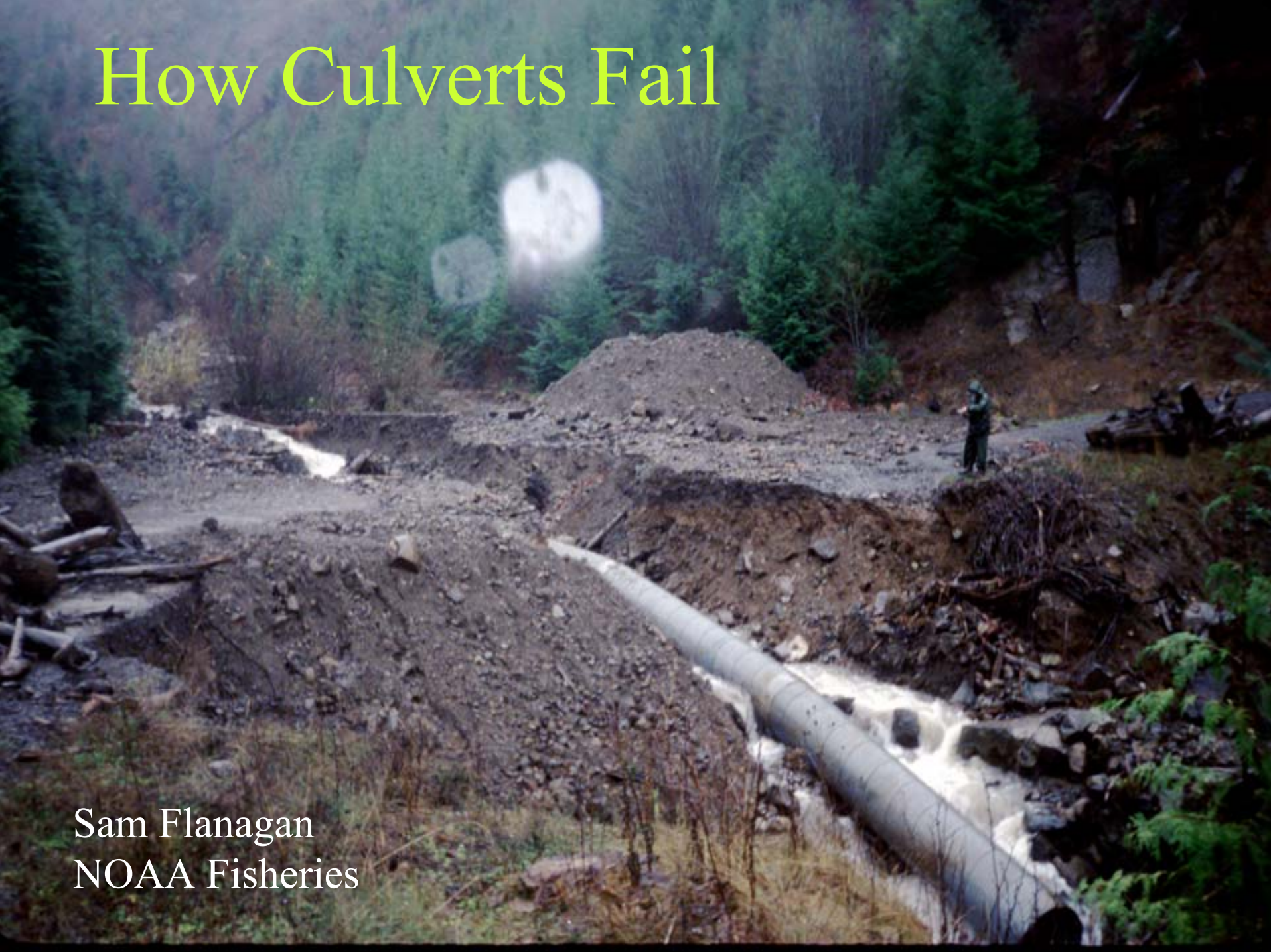
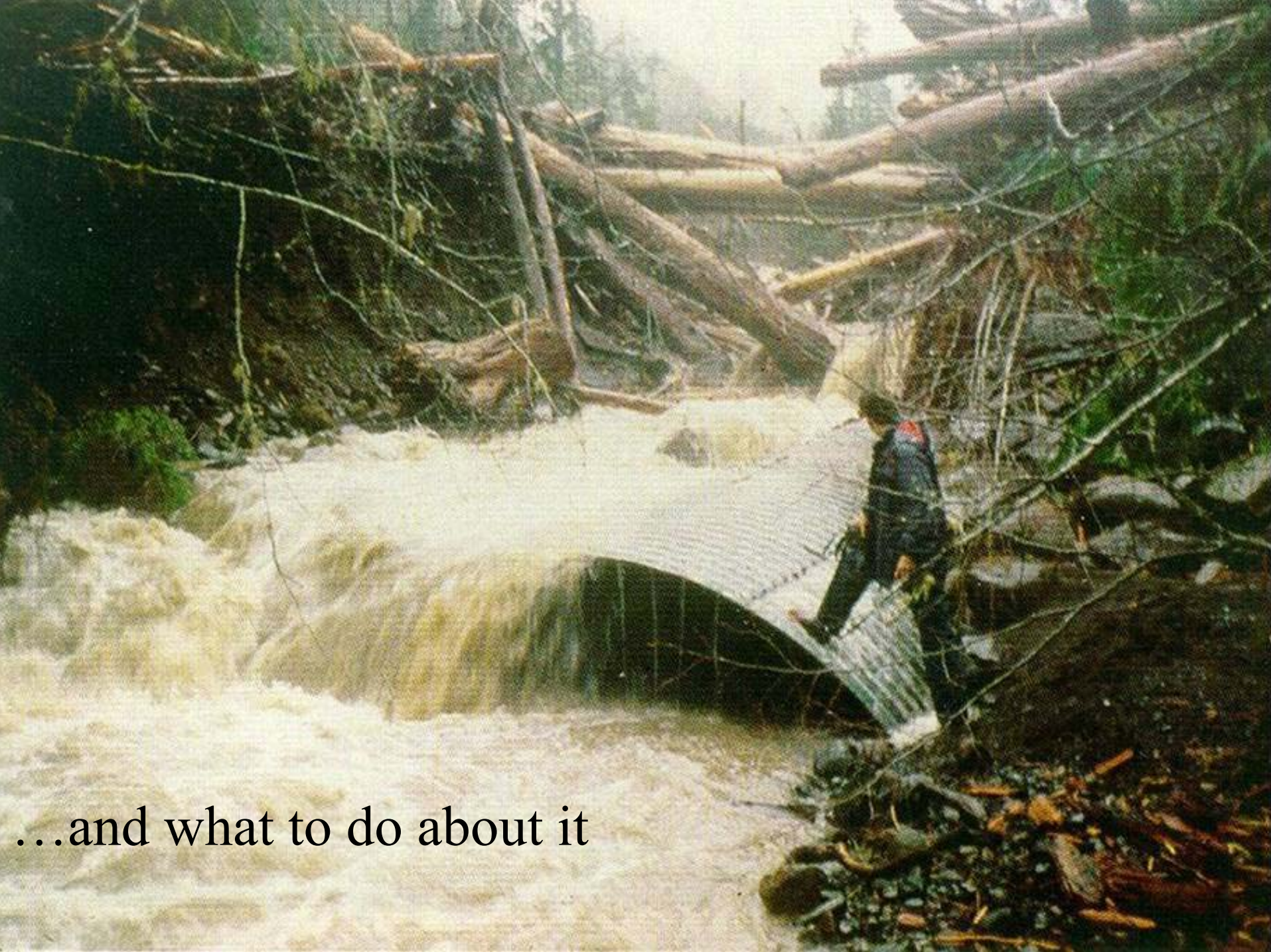


How Culverts Fail



Sam Flanagan
NOAA Fisheries

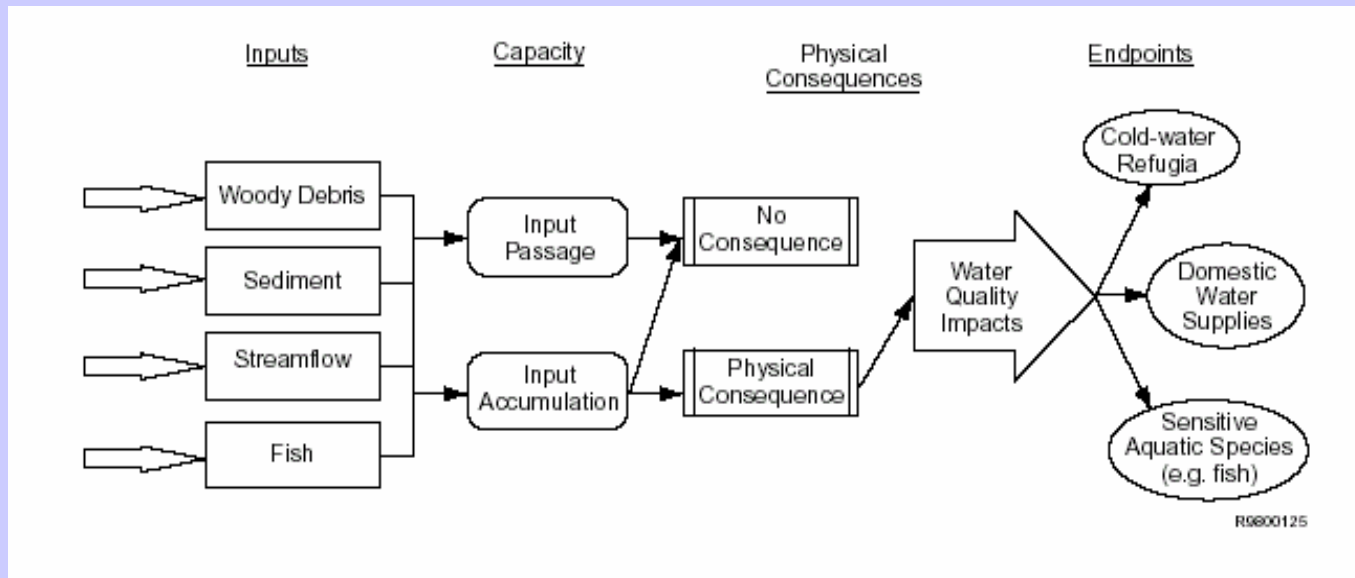


...and what to do about it

Chronology of Studies

- 1992-1996: Woody Debris Transport through Low-order Channels: Implications for Culvert Failure
- 1997: Field Indicators of Culvert Capacity
- 1996-1998: Response of Road-Stream Crossings to Large Flood Events in the PNW
- Funded by: CDF, HSU, USFS, NCASI

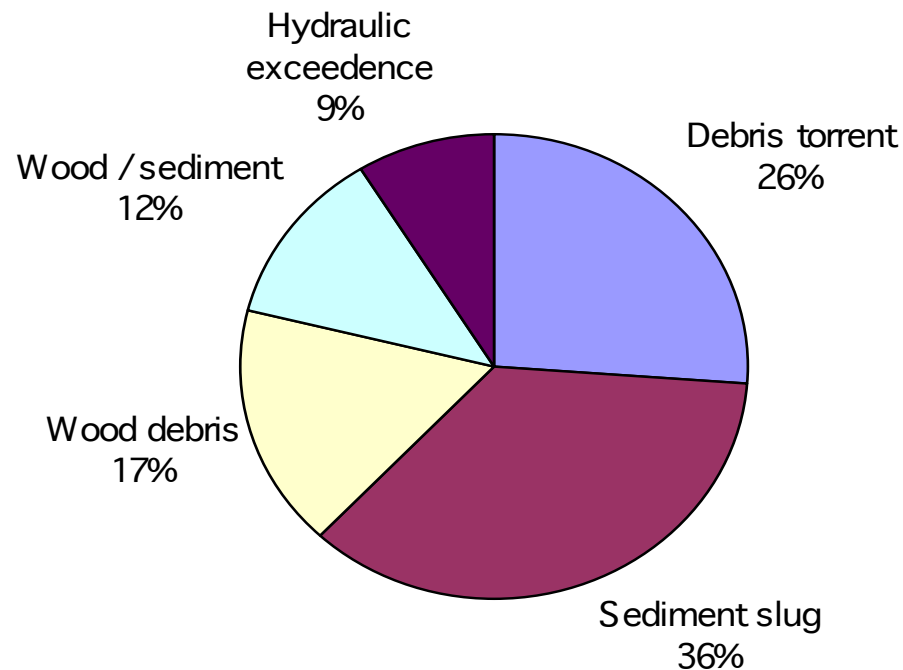
The Environmental Risk of Road-Stream Crossings



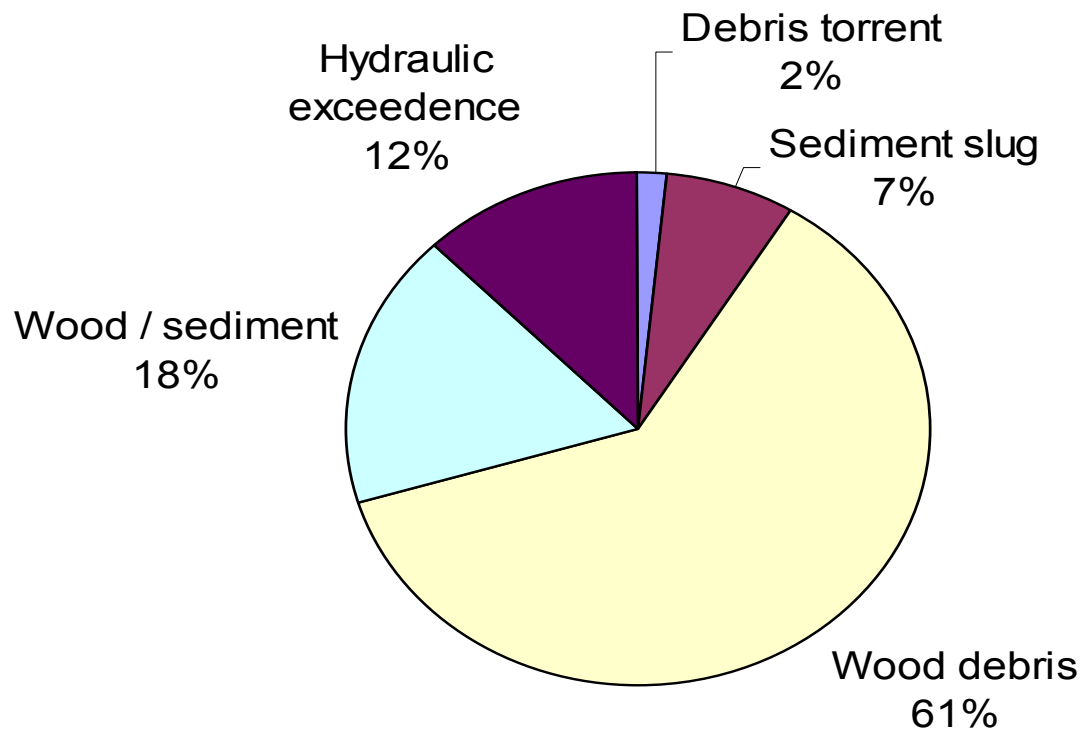
How do culverts fail?
What can we do about it?

A consideration of inputs and
capacity

Failure Mechanisms for the 1996/97 PNW storms (n=258) (a very large, infrequent storm)

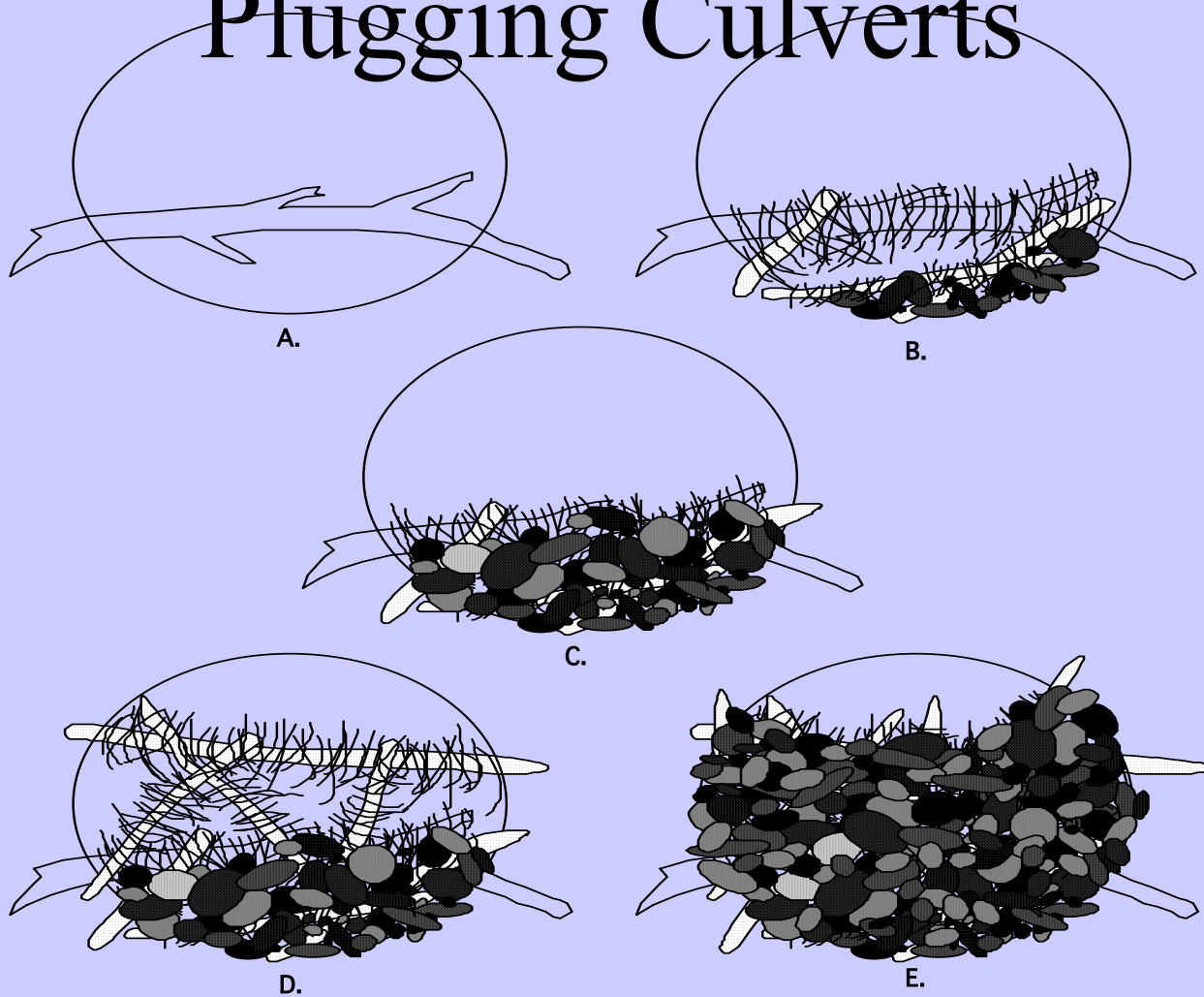


Failure Mechanisms for NW California (<12 year event)



Failure Mechanisms I.

The Phenomenon of Wood Plugging Culverts



Examine Wood Size Transported Through Low-order Channels

- 26 “Culvert-sized” streams
- Channel width ranging from 0.3 to 3.5m
- Construct debris screens across each stream

Debris Screens 15cm square mesh wire



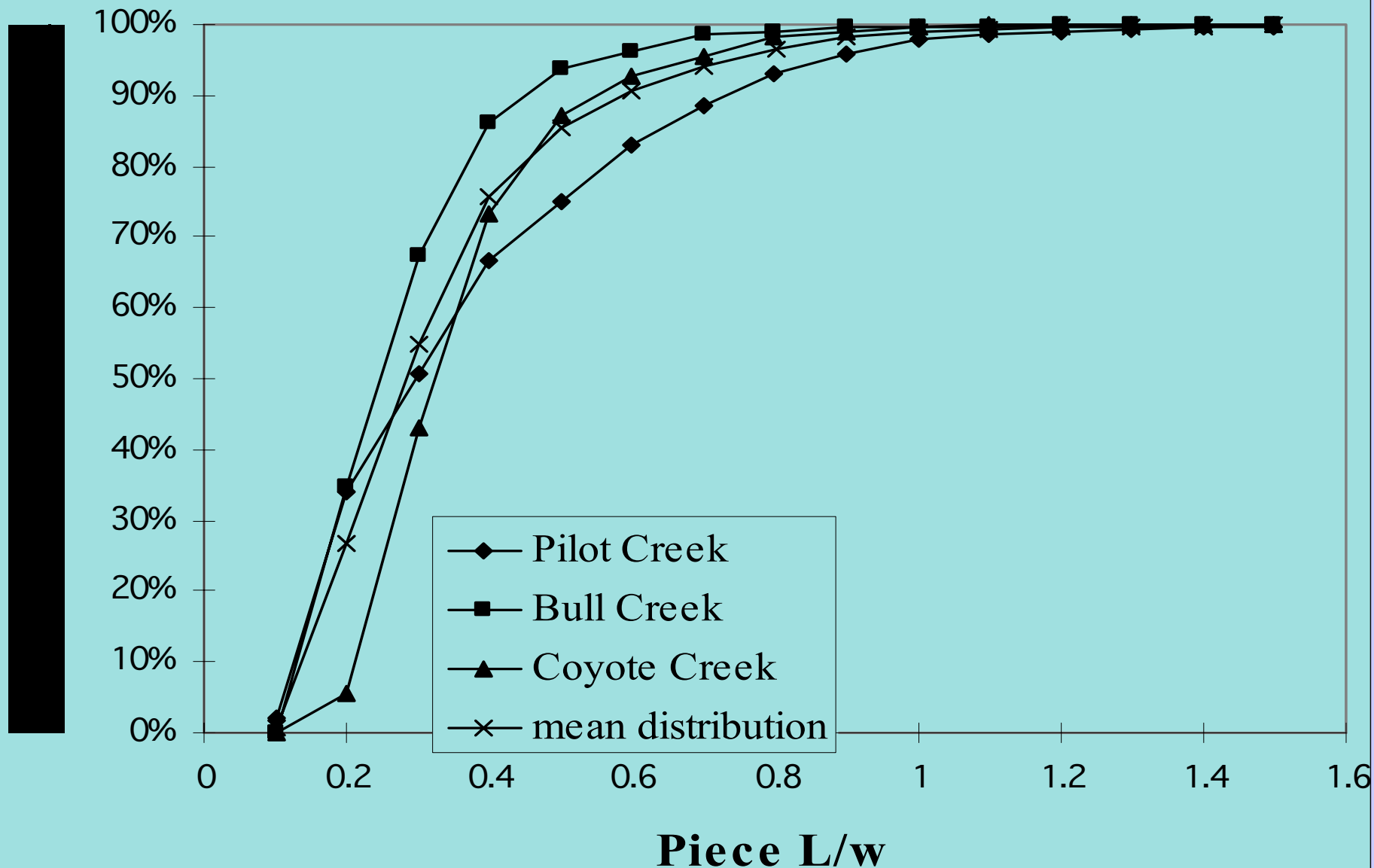
The Routine

- Collect wood accumulated in screens after each peak flow event
- Measure length and diameter of each piece
- Re-measure channel dimensions
- The joys of Storm Patrol
 - Sipping hot Tang
 - Access problems in and OUT due to landslides

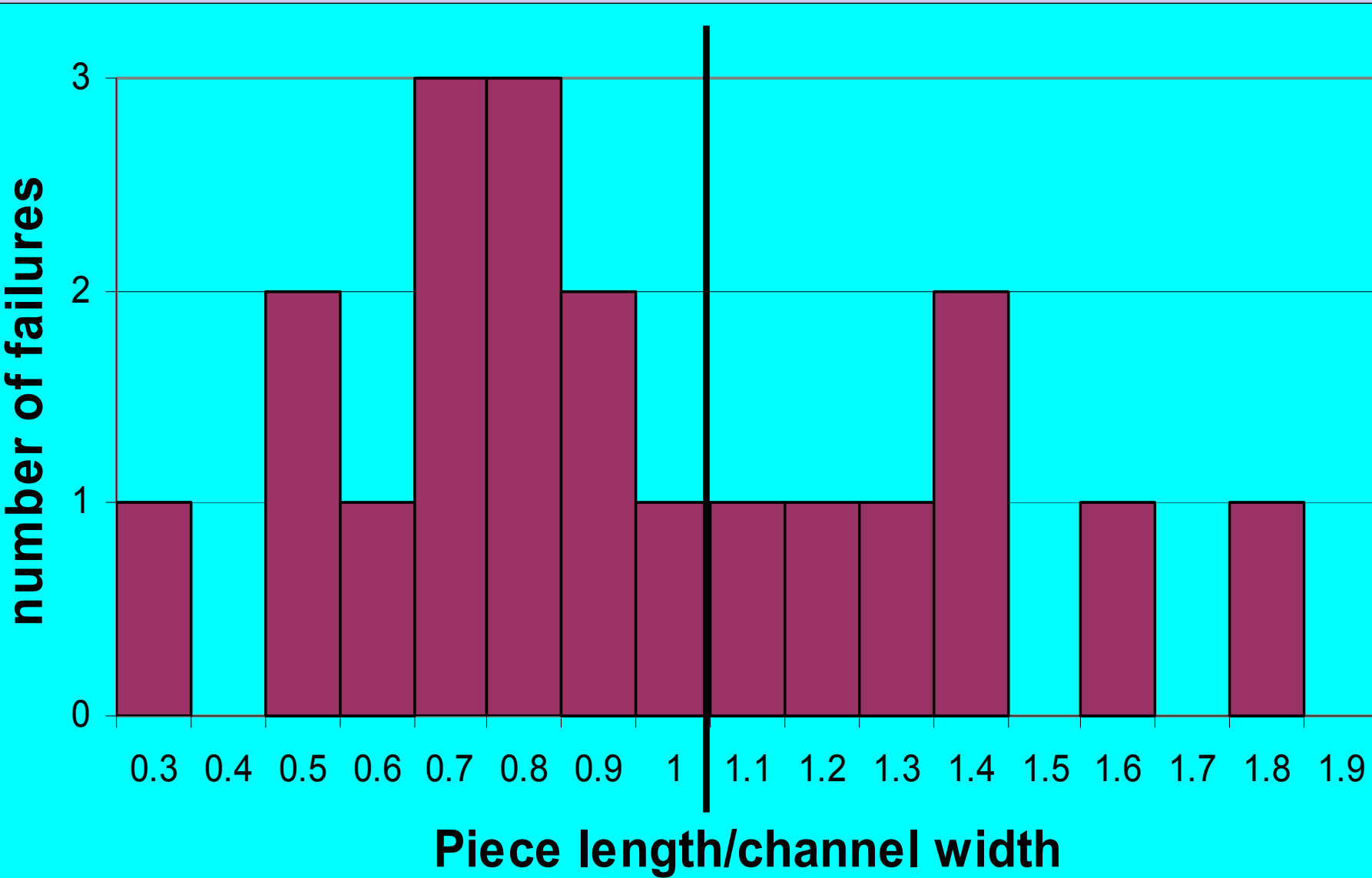
Findings

- 99.5 % of the wood transported through low-order channels is $<$ channel width
 - $n = 3,114$
 - 95th percentile wood length increases with channel width
 - Suggests woody debris supply to culvert is transport limited
 - Findings apply for storms $< \sim 12$ year event

Fluvially transported pieces are rarely greater than the channel width
In length (i.e. $L/w < 1$).



Wood lengths initiating plugging relative to channel width



Sizing Culverts to Accommodate Wood: Implications of Findings

- Culverts should be sized in relation to the “bed width”: the zone of active, annual scour and deposition
- Suggests that a culvert diameter that approximates the channel width reduces “fluvial wood” plugging potential - but does not eliminate the hazard

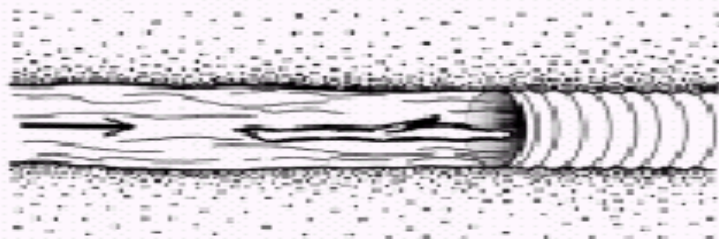
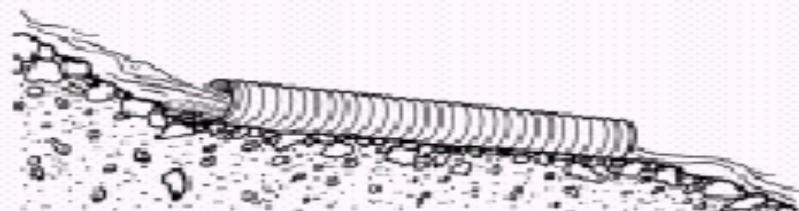
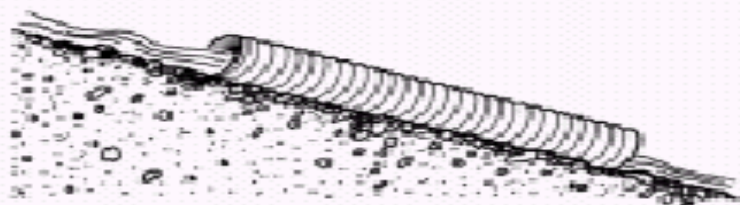
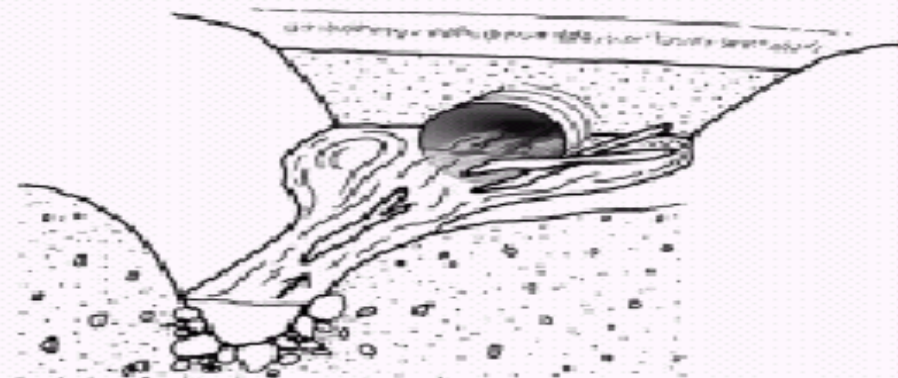
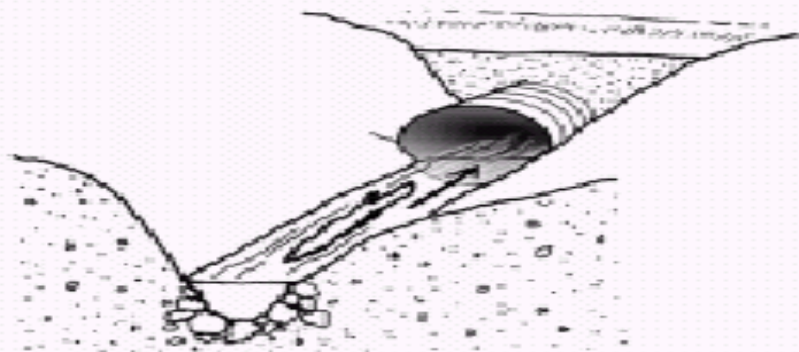
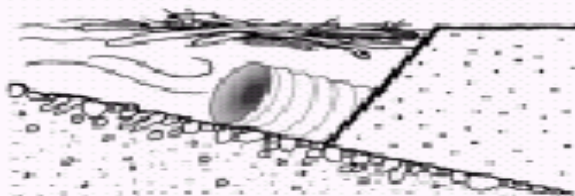
Anecdotes and Hypotheses

- Multiple barrel installations are not a suitable means of providing wood passage
- Inlet geometry influences wood orientation as it approaches

Increasing Plugging Hazard

HW/D < 1

HW/D > 1



Failure Mechanisms II.

Sediment

- Larger storms trigger a greater proportion of sediment-related failures
- Discuss (a) Fluvial sediment delivery versus (b) catastrophic sediment delivery (e.g. slides and debris flows)

A. fluvial sediment failure hazard

- Avoid placing relatively flat pipes on steep streams
- Two things working against this:
 - Flat pipe = a shorter pipe = less installation \$\$
 - Roads often built on natural hillslope benches that coincide with a short depositional reach in the channel

B. Debris Flow Failure Hazard



Addressing Debris flow failure hazard

- Minimize the interference that the crossing presents in the path of the debris flow
- Avoid rolling dips directly over the crossing or in the potential path of the debris flow
- The “cascading failures” observed by Grant et al.:

New slide initiated



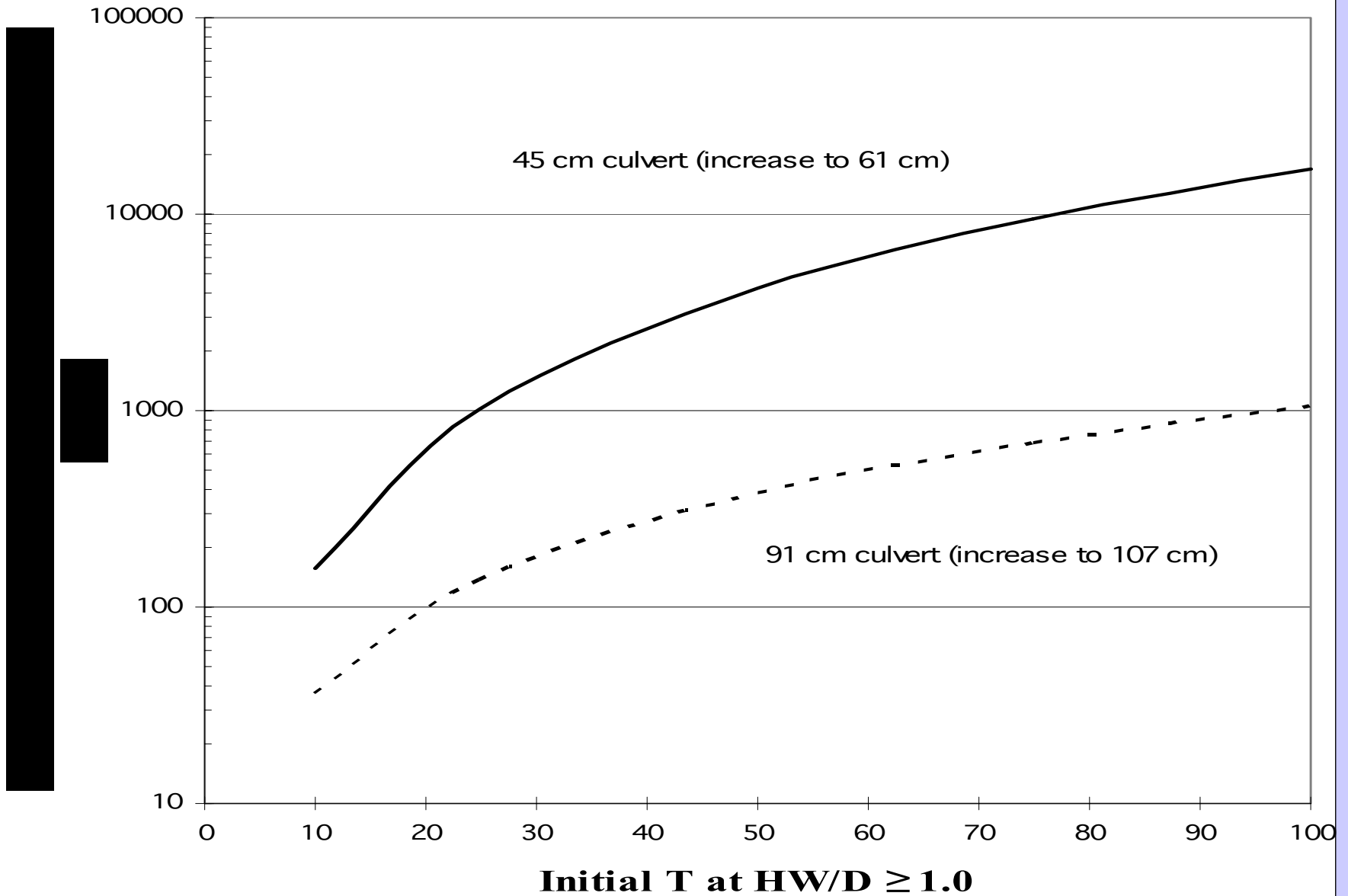
Water diverts to next crossing with further erosional consequences



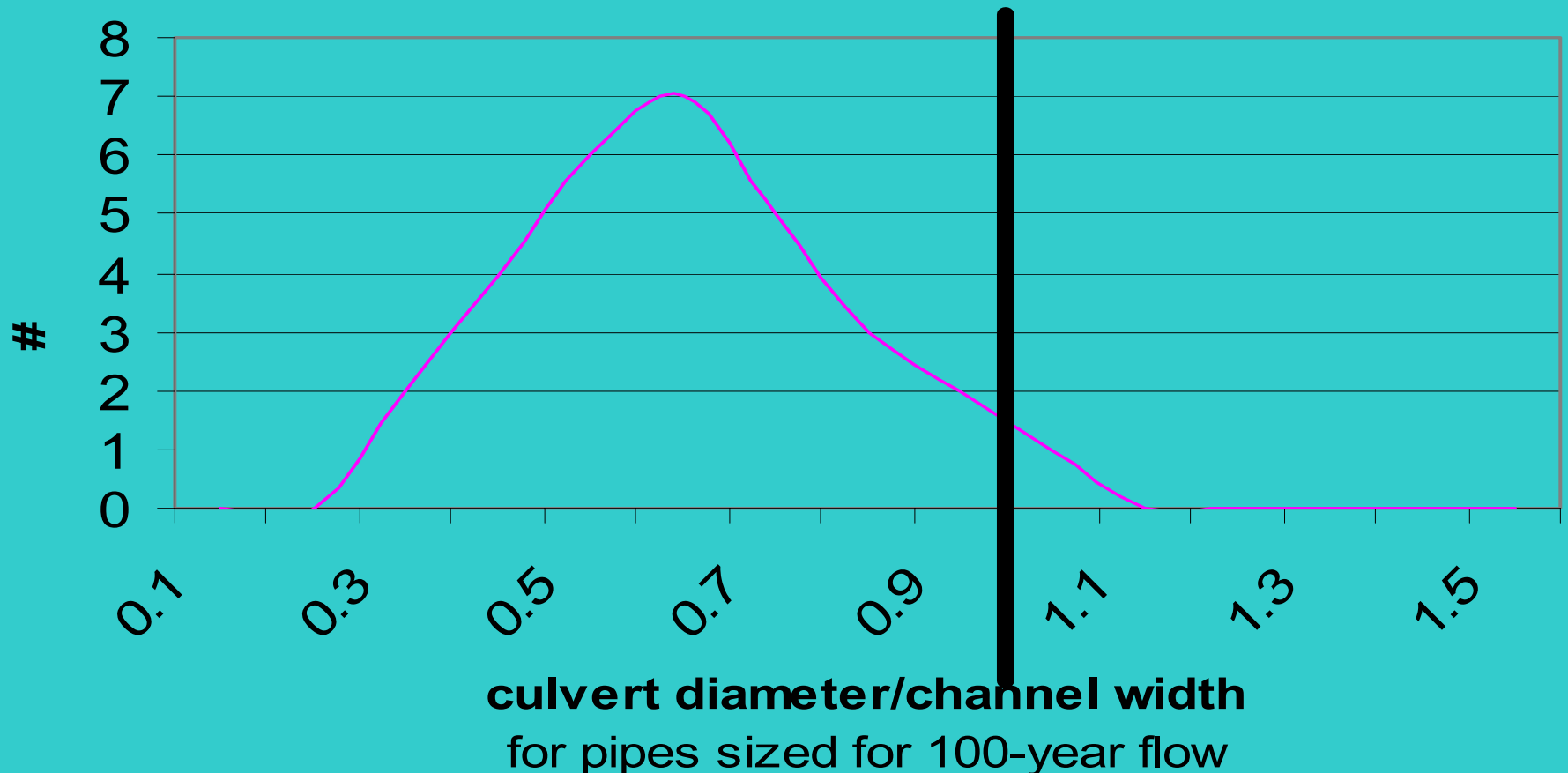
Failure mechanisms III. Insufficient hydraulic capacity

- Typically least frequent cause of failure
 - For forested, mountainous settings
- Is only a minimally useful measure for addressing failure hazard
- Why we shouldn't hang our hat on hydraulic sizing alone:

Effects of increasing pipe diameter one increment (6")



Sizing for 100 year “water” does not ensure adequate channel sizing for woody debris passage



Sizing for channel width typically ensures adequate hydraulic capacity

Failure mechanisms IV.

Culverts on small alluvial fans

- Roads, particularly low slope position, often traverse small alluvial fans
- The channel is prone to avulsion at the apex of the fan
- Channel is abandoned and no culvert is present on the road to accommodate the new channel location
- Relief culverts on each edge of the fan

Summary I – Styles of culvert failure

- More frequent storms cause failures by fluvial mechanisms – wood transport and fluvial sediment – we can reduce failure probability for these events
- Large, infrequent storms cause hillslope failures that initiate slides and debris flows – we can reduce failure consequences for these

Reducing fluvial failure probability

- Channel dimensions should drive culvert sizing
 - Channel width
 - Channel slope
 - Inlet basin configuration / approach angle
- Avoid sizing that creates ponded conditions

SIZING FOR A DESIGN
DISCHARGE SUCH AS THE 100-
YEAR PEAK FLOW

DOES NOT ENSURE ADEQUATE
CAPACITY FOR DEBRIS AND
SEDIMENT

Reducing failure consequences for large, infrequent storms

- AVOID DIVERSION POTENTIAL!
 - And be aware of the potential consequences of debris flows and adjacent slides overwhelming remedial dips
- Keep the watershed products moving downhill, not across the slope

(sidenote)

Existing culverts and channels often indicate past failures and types

- Dented inlets from repeat excavations
- Depositional terraces in the inlet basin
- Debris flow levees (may be well vegetated)
- A small pipe on a wide stream



Where roads cross streams, failure hazard can only be reduced, but not avoided, through careful design that accommodates water, wood and sediment, and potential erosional consequences when they do fail.